NGST Systems Engineering Report

Thermal Subsystem 12

Title:	
Overview of NGST Detailed OTA Thermal Modeling	
Date: 6/xx/98	Number:
Prepared by: Greg Schunk/OTA Thermal Analyst	
Concurrence: 	
References: 1. K. Parrish/GSFC, "Updated Thermal Modeling Process using FEMAP, TSS, TCON, and SINDA85 (THSER02)"presentation, 5-4-98 2. G. Schunk/MSFC,"NGST Architecture Trade Studies and Project Quarterly Review-OTA Thermal Analyses/Results Summary"presentation,10-8-97	

Abstract

This report provides an overview of the modeling process for the detailed thermal analysis of the NGST OTA. Brief descriptions of the thermal models, along with analysis assumptions, are also included. In addition to the system level NGST and detailed NGST/ISIM thermal modeling, the detailed thermal modeling of the OTA is a focus of the NGST thermal modeling effort. A discussion of the overall NGST thermal analysis effort is documented in Thermal SER 02 [1].

Modeling Objectives

The objectives of the detailed OTA thermal analysis are to: (1) predict the change in absolute temperature of the OTA between the ground and on-orbit environments and (2) predict the on-orbit steady state and transient thermal gradients in the OTA primary mirror and supporting structure.   The thermal analysis results are used to assess the optical performance of the telescope due to thermally induced displacements in the primary mirror and supporting structure. Transient thermal analyses are performed to determine the settling time of the OTA as the spacecraft slews between targets.

Modeling Tools

The detailed OTA thermal analysis activity utilizes two computer programs common to the solution of radiation heat transfer problems, the Thermal Radiation Analysis SYStem (TRASYS) and the Systems Improved Numerical Differencing Analyzer (SINDA). The specific versions used in the detailed OTA analyses are SINDA 85 version 3.1 and TRASYS version 2.8.

TRASYS is used to compute diffuse radiation conductors between surfaces based upon geometry and optical properties. TRASYS accepts a number of different graphic primitives ranging from simple polygons, rectangles, boxes, and cylinders to more exotic toroids and ogives. Models are constructed by positioning the graphic elements (using translations and rotations) relative to one another in x-y-z coordinate space and by defining optical properties for the resulting surfaces. Before the radiation conductors are computed, TRASYS first computes the form factors, followed by gray body interchange factors, between all of the surfaces in the model.

Two form factor calculation routines, based upon the Nusselt-Sphere and Double-Summation methods, are available with the Nusselt-Sphere method typically being the more accurate and more time consuming of the two. Options are available to control the number of radiation conductors retained for final output into the thermal network solution.

SINDA solves the thermal network resulting from radiation conductors computed by TRASYS and user defined linear conductors and imposed heat sources. Two different routines, depending upon whether a steady state or transient solution is desired, are utilized. The steady state routine uses a modified Aitken's Del-Squared process and the transient solution uses a forward differencing in time scheme with backward jumps to iterate to the proper temperature at each time step.

A third tool, developed in-house, is used to convert the NASTRAN geometrical data (triangular and quadrilateral finite elements) into TRASYS polygons. The NASTRAN finite element mesh is converted into a mathematically equivalent SINDA thermal network as shown in Figure 1. Internal structure, included as NASTRAN bar elements, is modeled radiatively with TRASYS and included in the SINDA thermal network solution as conductors derived from the effective cross sectional area and length. The resulting thermal models are able to provide a one-to-one nodal correspondence with the NASTRAN models while accounting for the thermal conductance within the primary mirror and secondary mirror mast and radiation exchange between all surfaces.

NASTRAN Finite Element   SINDA Thermal Network   TRASYS Representation
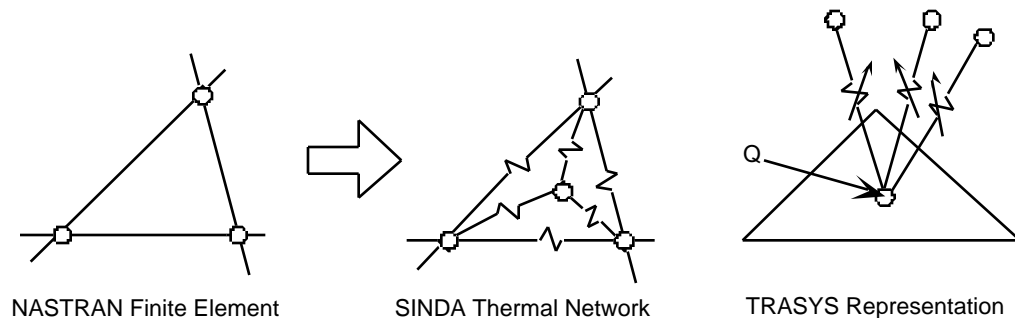
Figure 1 NASTRAN to TRASYS/SINDA Conversion

As shown in the figure, the NASTRAN nodal points are represented in the thermal network as SINDA arithmetic nodes. A diffusion node is added to the thermal network corresponding to the centroid of the element, providing a convenient location to impose heat loads and thermal mass and to attach radiation conductors.

Modeling Assumptions

The primary assumptions made regarding the detailed OTA thermal modeling are the thermo-physical properties of the materials used in the OTA design and the nature of the radiation heat transfer analysis. The materials used in the design of the OTA are beryllium, graphite-epoxy composite, titanium, and aluminum. To simplify the analysis, fixed (non-temperature dependent) properties for all of the materials are assumed. Conservative values (i.e. lower thermal conductivity for greater thermal gradient) are chosen where possible to mitigate the analysis uncertainty. For the metals, the thermal conductivity can vary significantly depending upon the purity of the alloy. For beryllium, values of 100 W/mK and 34.1 J/kgK are assumed for the thermal conductivity and specific heat, respectively, which correspond to a SR200 beryllium grade at 35K [1]. The thermal conductivities of titanium (4.22 W/mk) and aluminum (160 W/mk) are based upon values for pure metals at 40K from NBS data. The thermal conductivity of composite materials can vary widely based upon fiber orientation and volume fraction. For conservatism, a low

thermal conductivity of 1.0 W/mK is assumed for all OTA composites. Infrared emissivities of 0.03 and 0.70 are assumed for metallic and composite surfaces, respectively.

All OTA radiation analyses are conducted assuming diffusely emitting and reflecting surfaces. Although highly specular, it is assumed that the low profile of the primary mirror (due to the large radius of curvature) precludes a significant amount of specular interchange between the mirror petals or any other surface on the sunshade or secondary mast. The warm sun-shade is the primary influence upon the temperature of the OTA mirror and support structure. Because of the relative orientation of the mirror and sun-shade, most (if not all) of the energy incident upon the optic surface of the specular mirror from the sun-shade will be reflected into space or onto the secondary mast. Due to the large form factors of both the primary mirror and the sun-shade to space, it is assumed that the diffuse radiation model will adequately capture this behavior.

Modeling Process

The modeling process used in the detailed thermal analyses of the OTA is illustrated in Figure 2. Initially, a structural finite element model of the OTA is converted into a geometric model in TRASYS format and into a thermal network model in SINDA format. TRASYS models of the NGST sunshade and ISIM, provided by GSFC, are combined with the converted OTA thermal model. The integrated TRASYS model is executed to provide the radiation conductors necessary for the thermal network solution. Results from the GSFC system level analyses for the sunshade and ISIM are imposed as boundary temperatures within SINDA. The final results are obtained from the SINDA run.
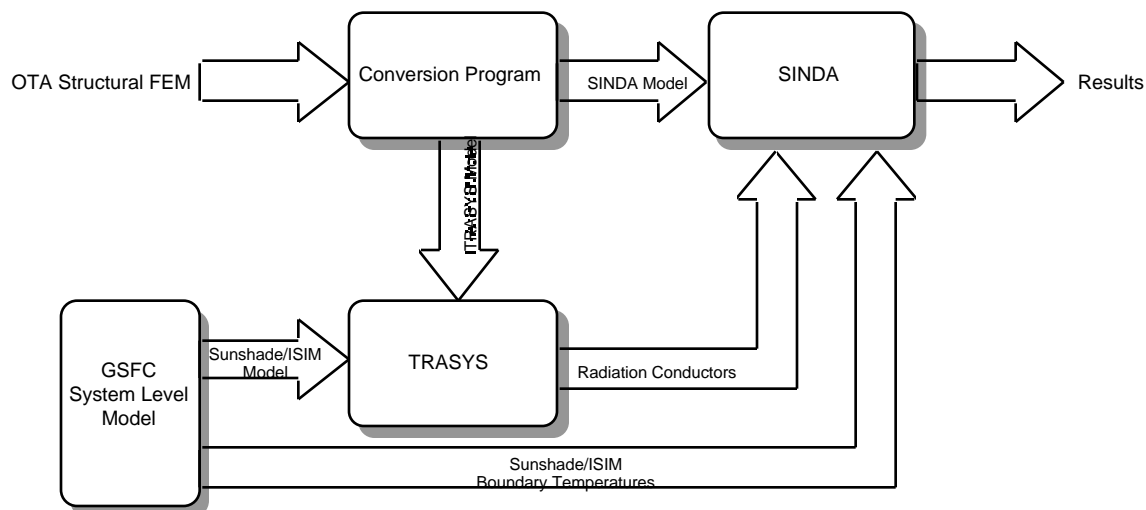

Figure 2 OTA Thermal Modeling Process

The three primary models used to support OTA trades and thermal analyses are shown in Figures 2, 3, and 4. The models represent an evolution in the OTA design as well as in modeling fidelity. The first model (Figure 2) is based upon a beryllium primary mirror with a graphite epoxy secondary mirror mast. Struts supporting the secondary mirror are not modeled radiatively, but are included conductively in the thermal network solution. Aluminum facesheets are utilized as close-outs on the back side of the reaction structure. An open-ended cylinder, intended to provide a rough approximation of the ISIM, is added to the bottom of the OTA. A simplified model of the sunshade (not shown) is developed from conceptual design drawings furnished by GSFC. The second model (Figure 3) is similar to the first, but featured an "open" reaction structure underneath the primary mirror. Like the first model, struts supporting the secondary mirror and in the primary mirror reaction structure are not modeled radiatively. Later revisions of this model incorporated a GSFC generated sunshade model. The most detailed and final model (Figure 4) integrated GSFC generated thermal models of the sunshade and ISIM and featured a detailed model of the

reaction structure truss supporting the primary mirror. All of the reaction structure and the secondary mirror support structure is modeled radiatively. The OTA design is all beryllium except for the titanium actuator pins that support the primary mirror. The geometry of the secondary mirror mast is different from previous design iterations.

Figure 2 OTA Thermal Model (circa 4/97)
Be Primary Mirror/GrEp Seconday Mirror Mast/Aluminum Facesheets

Figure 3 OTA Thermal Model (circa 6/97)
Be Primary Mirror/GrEp Seconday Mirror Mast/"Open" Reaction Structure

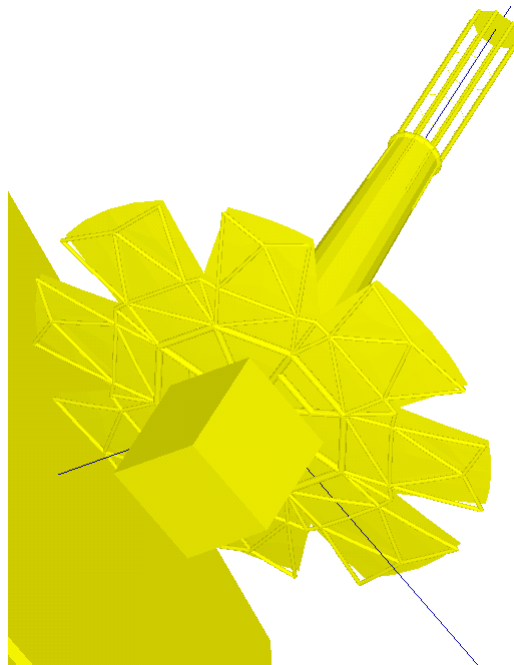

Figure 4 OTA Thermal Model including ISIM and Sun-Shade (circa 11/97)
All Beryllium Primary Mirror/Seconday Mirror Mast

A summary of the features of each of the three primary models are provided in Table 1. The table includes several variations of the models that were developed to support trades and analyses examining the impacts of removing the secondary mirror mast, adding

conductive straps within the reaction structure, and an open versus closed reaction structure. The large number of radiation conductors for the all-beryllium yardstick design results from the radiative modeling of the support structure struts for the primary and secondary mirrors as well as a change in the radiation conductor cull setting, RKMIN, within TRASYS.

Table 1 OTA Thermal Model Overview

Model Description	Based on XXX SRTM Model	Primary Mirror Material	Secondary Mirror Material	Reaction Structure Design	Radiative Struts	Sunshield Model Origin	ISIM Model Origin	Transient Version	Steady State Version	Number of Nodes	Number of Radiation Conductors	Number of Linear Conductors	Hinge Approval	Latch Approval	Conductive Straps
Original Be/GrEp Baseline	Apr-97	Be	GrEp	Aluminum Facesheet	No	MSFC	N/A	No	Yes	1732	37843	8770	Yes	No	No
Original Be/GrEp Baseline w/ No Mast	Apr-97	Be	GrEp	Aluminum Facesheet	No	MSFC	N/A	No	Yes	1524	27597	7587	Yes	No	No
Original Be/GrEp Baseline w/ Straps	Apr-97	Be	GrEp	Aluminum Facesheet	No	MSFC	N/A	No	Yes	1732	37843	8778	Yes	No	Yes
Updated Be/GrEp Baseline	Jun-97	Be	GrEp	Open Be Struts	No	GSFC	N/A	Yes	Yes	1708	15566	6946	Yes	No	No
Updated Be/GrEp Baseline w/ Close-Outs	Jun-97	Be	GrEp	Aluminum Facesheet	No	GSFC	N/A	Yes	Yes	2164	54783	9250	Yes	No	No
All Beryllium Yardstick Design	Nov-97	Be	Be	Open Be Struts	Yes	GSFC	GSFC	Yes	Yes	1810	164402	5874	Yes	Yes	No